Using biotelemetry to develop and optimize escapee recapture methodologies for the aquaculture industry

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Using biotelemetry to develop and optimize escapee recapture methodologies for the aquaculture industry

by

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ABSTRACT

Bridger, C.J., Booth, R.K., McKinley, R.S., and Scruton, D.A. 2004. Using biotelemetry to develop and optimize escapee recapture methodologies for the aquaculture industry. Can. Tech. Rep. Fish. Aquat. Sci. 2565: 12 p.

Escapement of aquaculture fish is an area of much concern. Escapement may result in undesirable interactions between wild stocks and domestic strains of salmonids, in addition to substantial financial loss to the aquaculture industry. A practical solution to escapement may be to recapture escapees and return them to the cages for further growth. Methods to monitor escapee behavior and to develop potential recapture strategies are required to develop optimal recapture solutions for specific aquaculture industries and locations. Biotelemetry may offer a means to determine fishing success of candidate recapture strategies from a passive perspective, unlike other suggested methods of observation – diving, underwater cameras, and hauling traps at specific fishing times. In this report we describe a simple, and relatively inexpensive, use of telemetry to monitor fish movement relative to a recapture trap, outlining the required methodology and calibration, data analysis, and the benefits and limitations of using this specific telemetry approach.

RÉSUMÉ

Bridger, C.J., Booth, R.K., McKinley, R.S., and Scruton, D.A. 2004. Using biotelemetry to develop and optimize escapee recapture methodologies for the aquaculture industry. Can. Tech. Rep. Fish. Aquat. Sci. 2565: 12 p.

L'évasion de poissons d'élevage suscite beaucoup d'inquiétude. Elle peut aboutir à des interactions indésirables entre les stocks sauvages et les souches indigènes de salmonidés, ainsi qu'à d'importantes pertes financières pour l'industrie de l'aquaculture. Une solution possible à ce problème d'évasion consisterait à recapturer les poissons évadés et à les remettre dans les cages pour qu'ils continuent à y grandir. Des méthodes de surveillance du comportement des évadés et d'élaboration de stratégies de recapture éventuelle sont nécessaires pour offrir des solutions de recapture optimales à des industries aquacoles et des lieux d'élevage spécifiques. La biotélémétrie pourrait être un moyen de déterminer le succès qu'offrent diverses stratégies de recapture possibles et cela de façon passive, contrairement à d'autres méthodes d'observation suggérées, comme la plongée, l'utilisation de caméras sous-marines, et la levée de pièges à des périodes de pêche déterminées. Le présent rapport décrit un moyen simple et relativement peu coûteux d'utiliser la télémétrie pour surveiller les déplacements du poisson par rapport à un piège de recapture; il donne un aperçu de la méthode et de l'étalonnage nécessaires, de l'analyse des données ainsi que des avantages et limites de l'utilisation de cette méthode de télémétrie.

INTRODUCTION

Escapement of aquaculture fish into the wild is an area of much concern. With the intensive use of open-ocean grow-out cages in the aquaculture industry, an increased risk exists for the loss of domestic strains of fish into the wild. It has been predicted for certain areas of western Europe and northeast North America that the number of escaped or deliberately released cultured salmon may be equal to or greater than the number of wild salmon (Saunders 1991). Although the numbers of escapements are declining with increased industry awareness to the economic loss and negative ecological impacts, and resultant local Aquaculture Code of Practice (Newfoundland Salmonid Growers Association, personal communication), escapement of salmonids still occurs in Bay d'Espoir, Newfoundland.

Unrecoverable escapement of domestic stocks and its associated financial loss is a major concern to the aquaculturist. In addition, escapement may result in undesirable interactions between wild stocks and domestic strains. It is unclear whether such interactions have negative effects on wild stocks but specific concerns include disease, ecological and genetic interactions with wild fish stocks (Hansen et al. 1991; Hutchinson 1997). Compelling evidence has recently been collected for aquaculture site fidelity in domestic triploid steelhead trout (Bridger et al. 2001). Following summer escapement, 75% of escaped triploid steelhead trout demonstrated fidelity to the grow-out cages for more than 30 days following their release. Large populations of wild fish have also been reported in the vicinity of aquaculture cages (Beveridge 1984; Carss 1990). Although homing cues to aquaculture sites are yet uncertain, they may involve increased feeding opportunities near the cages, an attraction to the physical structure of the cages or a schooling influence to other fish.

In addition to financial loss, aquaculture site fidelity expressed by escapees pose several additional concerns for the aquaculture industry. First, homing domestic salmonids may be in close contact with both wild and aquaculture stocks. Close contact may enhance horizontal disease and parasite transmission between wild and domestic counterparts (Johnsen and Jensen 1985; Håstein and Lindstad 1991; Lund and Heggberget 1992; McVicar 1997). Second, large concentrations of fish present outside the cages may attract predators to the site that may also act as disease vectors (Beveridge 1984). Finally, a risk exists that escapees may contain residues of antibiotics and are captured in either a commercial or recreational fishery. Antibiotic residues may have occurred from treatment prior to escapement or feeding on medicated feed falling through the cage uneaten. Drug residues have been found in wild fish captured in the vicinity of aquaculture cages, and with such a high degree of fidelity, the same could be expected for escapees (Björklund et al. 1990; Ervik et al. 1994).

Owing to these implications, it should be the goal for all aquaculturist to control or completely eliminate fish loss from cages. Complete elimination may be considered unrealistic owing to the harsh and sometimes unpredictable environment of open-ocean aquaculture. An alternative and more practical solution may be to recapture escapees and return them to the cages for further growth. Efficient development of optimal recapture strategies for any aquaculture industry should logically follow three phases. The first would

be to determine the movement and behavior of escapees in the wild to ensure effective recapture is feasible. This phase has been completed for triploid steelhead trout in Bay d'Espoir, NL with these escapees demonstrating a high degree of aquaculture site fidelity following escapement (Bridger et al. 2001).

Next, an effective method to evaluate, monitor and develop potential recapture trap configurations should be developed. Finally, potential recapture traps would need to be tested to develop optimal recapture strategies for the industry. These phases have also been the focus of recent preliminary research in Bay d'Espoir (Anonymous 1999). Prototype recapture strategies were evaluated by hauling candidate trap configurations at set intervals to determine recapture success. These field trials documented the first successful escapee recapture in Bay d'Espoir. Several additional questions were posed following this success as to why some strategies were more effective and how some fish avoided the candidate recapture strategy. Researchers suggested the use of divers and underwater cameras may provide insight to answer such questions. However, these techniques will be time consuming, require day-light hours for data collection, and may provide inaccurate conclusions owing to the intrinsic invasive approach of using divers an cameras to monitor fish behavior.

This paper will focus on the second phase to develop effective recapture strategies by describing a telemetry system to evaluate possible recapture traps for the salmonid aquaculture industry. A telemetry approach will allow ease of monitoring, from a passive perspective, of candidate recapture trap configurations and optimize development of the most appropriate approach. This telemetry technique was field tested with a prototype trap and monitored domestic triploid steelhead trout (*Oncoryhnchus mykiss* Walbaum) in Bay d'Espoir, NL, Canada.

METHODS

The study was performed at the Conne River Aquaculture overwintering site in Bay d'Espoir, Newfoundland in December 1998. A trap was deployed within the site to determine the feasibility of using telemetry to monitor its fishing success. The trap had a similar configuration to a traditional Newfoundland caplin trap and was affixed to a plastic collar fish culture cage with a 15 m leader heading for shore. Two hydrophones were used to monitor the trap for nearby acoustic signals from transmitters surgically implanted into triploid steelhead trout (Fig. 1). An omnidirectional hydrophone (B) was placed in the center of the trap and configured to only monitor within the cage. This hydrophone gave a presence/absence record for tagged triploid steelhead within the trap. Another hydrophone (A) was configured to monitor the leader. It was placed at the near-shore end of the leader and fitted with a 270° baffle, with the open 90° pointing along the leader towards the trap entrance. Both hydrophones had cables running towards shore where the receiver and necessary electronic components were housed.

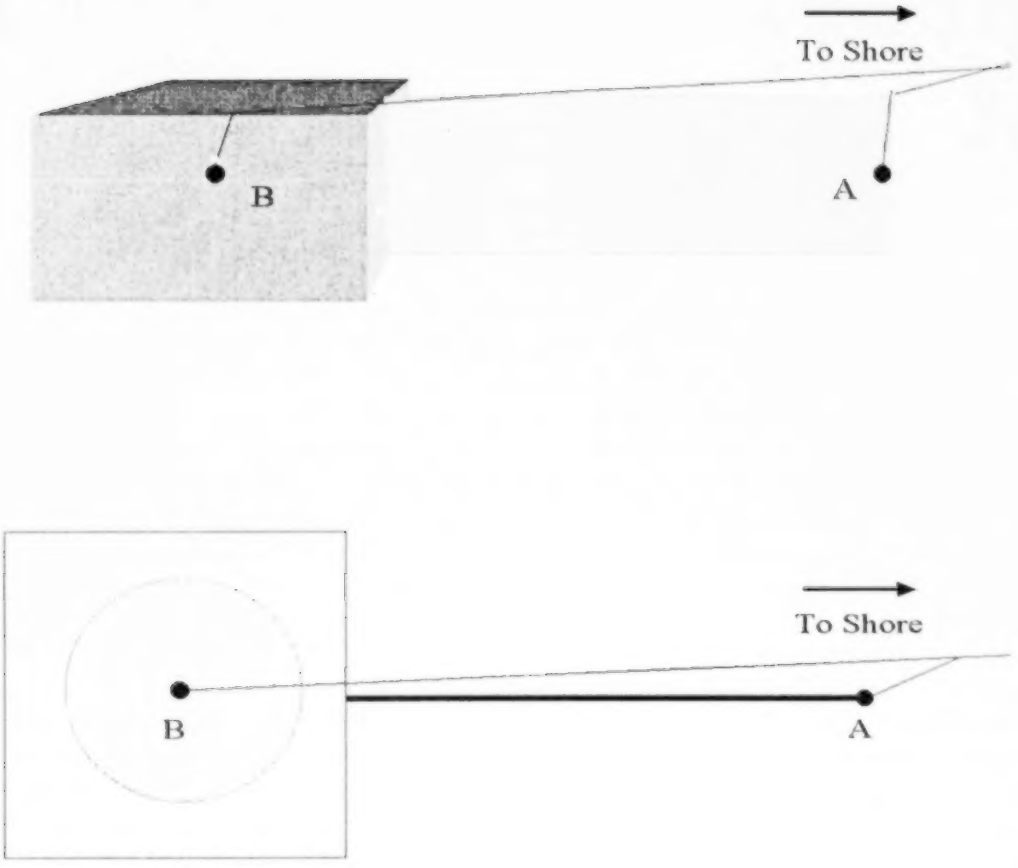

Figure 1. Recapture trap with monitoring hydrophone locations. Plane view (upper); Top view with trap hydrophone coverage area (stippled area; lower).

A Lotek SRX_400 radio receiver was used to monitor the hydrophones. As a radio receiver cannot process acoustic frequencies, each hydrophone was connected to an individual Lotek Ultrasonic Upconverter (UUC) which converts the electrical signal from the hydrophone to a SRX compatible radio frequency for the receiver to process. The SRX received, processed and logged identification codes and time of transmissions within the range of each of the hydrophones. In addition, each received transmission had an associated power level which is indicative of the distance between the transmitter and receiving hydrophone.

Each hydrophone was calibrated as required for appropriate data collection. For trap calibration, a single transmitter was placed in the water at several points around the trap with the SRX monitoring the trap hydrophone (B). The hydrophone gain was set so the hydrophone could not receive transmissions originating outside the netting. This was to ensure the hydrophone would only receive signals from fish clearly within the trap (Fig. 1; stipple area).

It was necessary to calibrate the leader hydrophone (A) so that the movement of transmitter implanted fish could be monitored as the fish responded to and moved along the leader. Gain for the leader hydrophone was initially set to only monitor the length of the leader. It is generally accepted that signal power levels will be greatest when the transmitter is closest to the receiving hydrophone. From this assumption and leader hydrophone location, the highest power levels would have been recorded nearest to shore with a steady decrease in the signal strength as the fish moves from the hydrophone to the trap entrance with the lowest levels at the trap entrance. With the gain properly set, transmitted signals should not be received by hydrophone A as the fish enters the trap. Owing to environmental (depth, conductivity and temperature) and fish/transmitter orientation effects on signal strength, received power levels will not be constant for each point along the leader but remain fairly consistent within a specific range. This range will have a probability density function (p.d.f.) approximating a normal distribution and symmetric standard deviation with the upper tail missing (Fig. 2). This lower tailed p.d.f. occurs because most of the power levels from a given point is centered around the mean (most likely signal strength for the environment and distance from the hydrophone) with some power levels diminished slightly along the propagation path (lower tail values). Values above the mean may be considered optimal for that distance if the system was monitoring in a stable environment. With an ample duration of calibration and an infinite number of calibration stations along the leader, a continuum of power levels would be realized for the length of the leader. The mean for each station would then correspond to a received power level and used to track fish movement along the leader with a high degree of certainty for predicting the movement pattern.

This degree of calibration, however, requires a substantial amount of effort and not considered feasible for a field study. To decrease the calibration effort, calibration is performed at a minimum of three points along the leader; nearest to the hydrophone, middle, and entrance to the trap (Fig. 3). A single transmitter was used for the calibration by placing the transmitter at mid-leader depth at each location. The transmitter was attached to the head rope of the leader and monitored by the SRX for a minimum of 5 minutes. The acoustic transmitters had a 10 second repetition rate thereby transmitting 30 signals during this minimum time span.

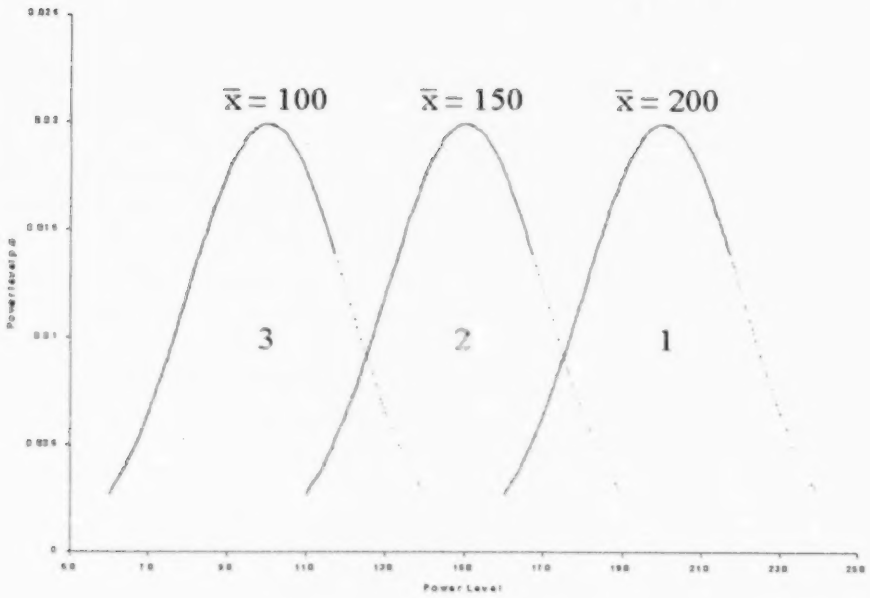

Figure 2. Theoretical probability density function of power levels from each point of leader calibration. Dotted lines complete each normal p.d.f. and vertical lines illustrate upper tail endpoints for each plot.

With ample calibration, all possible power level values will be recorded from at least one of the calibration points along the leader. In this manner, power levels from fish tracking may be placed at one of the calibration points with a degree of certainty defined by the calculated p.d.f.. For three calibration points described here, the expected mean power level attained along the leader would be 100, 150 and 200 for the far, middle and near calibration points in relation to the hydrophone, respectively (Fig. 4). Calibration plots may have a certain amount of overlap between power levels of nearby calibration points. However, the calculated p.d.f. will determine the nearest calibration point from which the received power level originated. In circumstances where the p.d.f. plots from nearby calibration points cross, fish position may be placed between the calibration points. Although this may not occur often, coupled with subsequent values, it may provide a more complete picture of fish movement with time. Fish positioning may be superimposed on the trap and leader to determine the expected fish tracks (Fig. 4).

CART 16_1 transmitters (Lotek Marine Technologies Inc., St. John's, NL) were used for the feasibility study. Each transmitter was cylindrical, measuring 16 mm diameter by 75 mm length and 16.6 g fresh water weight. Transmitters were surgically implanted into 30 triploid steelhead trout according to Bridger et al. (2001). Fish were allowed to recover from surgery in a designated holding pen for 48 hours. Release was accomplished by dropping the

net of the cage and allowing transmitter implanted triploid steelhead to swim freely from the cage structure.

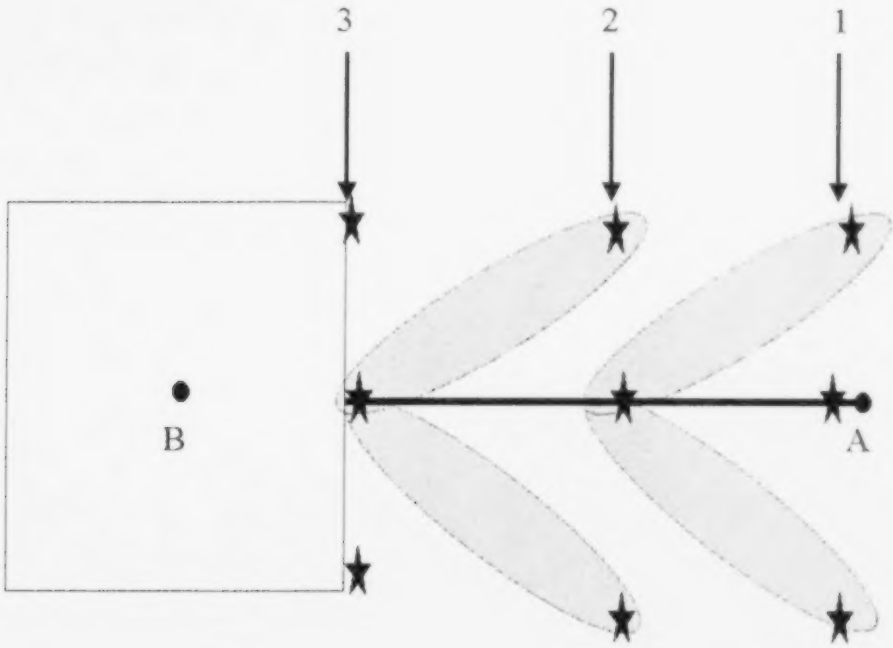

Figure 3. Trap calibration illustrating zones of similar power levels received by the receiver (gray area). ★ represents exact points of leader calibration. Numbers represent calibration regions along the leader.

Triploid steelhead movement in the vicinity of the trap was collected for 4 days. The trap had an open entrance with no reverse winkers – lengths of netting to prevent escape of captured fish – at the trap entrance, thereby allowing the fish to swim freely in and out of the trap. In the absence of reverse winkers, there was no need to remove any fish from the trap during the project. Data was downloaded to a laptop using the Lotek Wildlife Host program and copied to Microsoft Office Excel and Minitab for Windows release 9.2 for analysis and plotting.

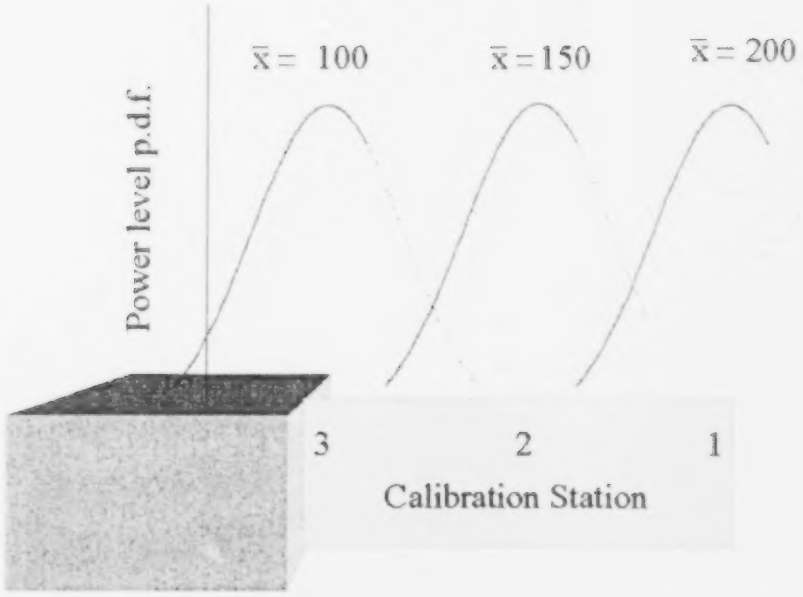

Figure 4. Probability density function superimposed on the recapture trap to determine fish movement along the leader.

RESULTS

SYSTEM CALIBRATION

Field calibration along the leader (Fig. 5) was similar to the theoretical calibration plot (Fig. 2). Owing to different standard deviations of each of the data sets, normal distributions of the data had slightly different shapes. Much more overlap was evident between the middle calibration station and the stations at both ends of the leader. In addition, the mean value (130.21) of the furthest calibration station was much higher than the expected mean (100). The other two calibration points had means close to the anticipated mean.

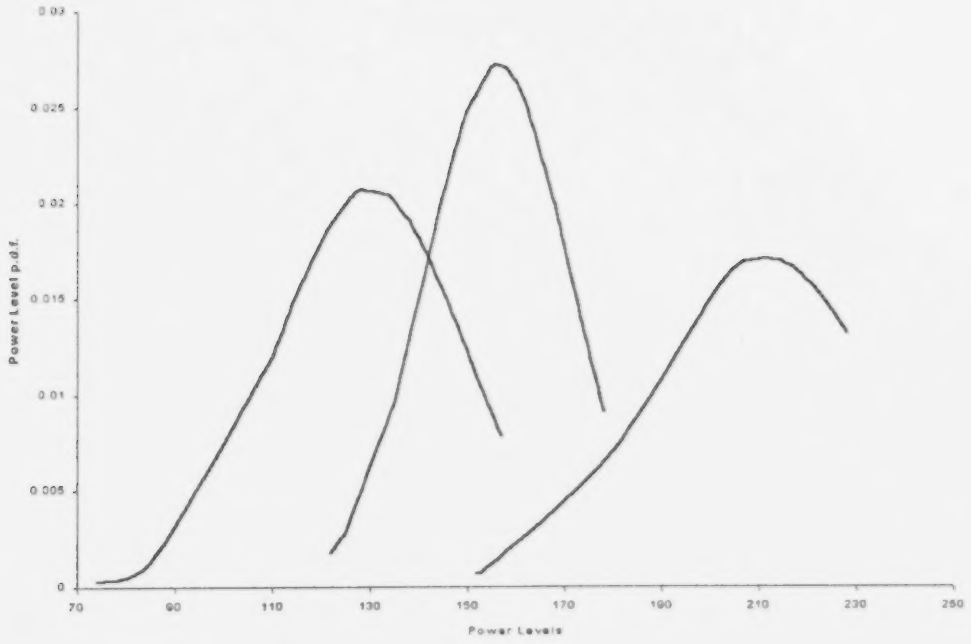

Figure 5. Probability density function of field collected power levels during leader calibration.

STEELHEAD MOVEMENTS

Probability density functions (p.d.f.) attained from the calibration data (Fig. 5), were used to plot and superimpose triploid steelhead movement along the leader (Fig. 6). Figure 6 gives examples of steelhead movement as determined from received power levels and comparison with the calibrated p.d.f. of Figure 5. Illustrated are three movement scenarios with respect to the trap and leader. Tag 99 was first received with a power level of 219. From this, it may be assumed that the steelhead approached the hydrophone from its baffled side. Following the leader encounter, the steelhead turned and swam away from it. Tag 91 gave contrasting results with the steelhead swimming along the length of the leader. However, it appears that the fish followed the leader to the trap entrance, then either rounded the end of the leader and followed it again on the other side or at the entrance reversed it direction to swim back along the leader, without ever entering the trap. It should be noted that it cannot be determined which side of the leader the fish is on but only the direction of movement along the leader from received power levels. Tag 98 also followed the leader and entered the trap for an extended period of time, determine from signals received by

Hydrophone B. With numerous signals received from the transmitter in the trap, it is most logical to assume the steelhead completed several trips around the inside of the trap and not remain stationary upon entering. In the absence of reverse winkers, the steelhead eventually found its way out of the trap and swam away.

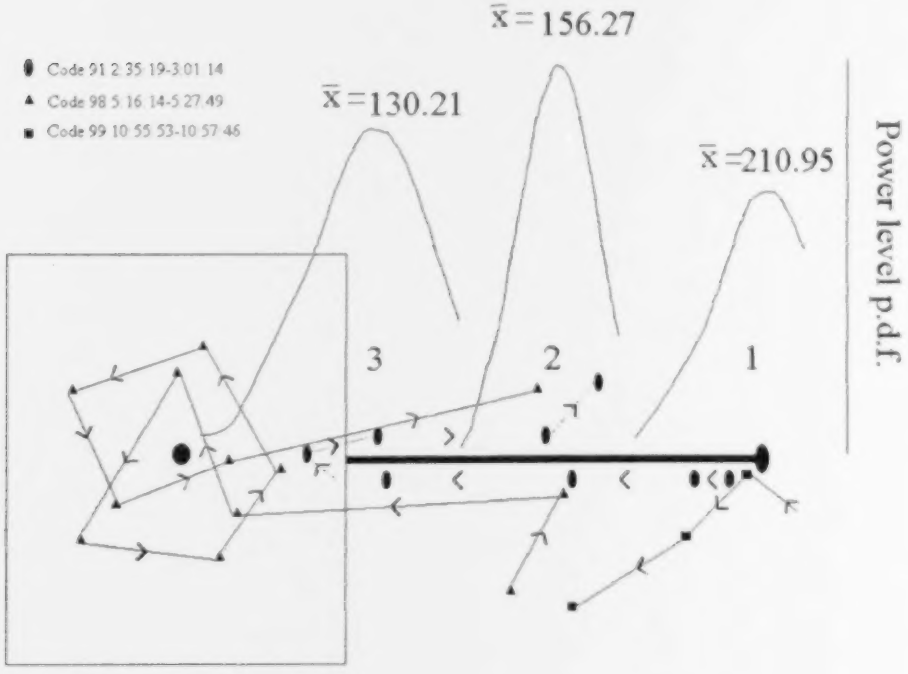

Figure 6. Triploid steelhead trout movement with respect to the recapture trap leader as determined from received power levels and leader superimposed p.d.f..

DISCUSSION

Previous methods employed to monitor the effectiveness of potential recapture traps have involved closing the trap and hauling it at set intervals to determine its fishing success (Anonymous 1999). This approach is labor intensive and does not give a detailed description of the fish behavior with respect to the trap and leader with only the quantity of fish captured at discrete time intervals determined. With this approach, optimal fishing duration may not be determined as fish may only be retained for a duration within these intervals (i.e. the trap may be hauled every 6 hours but the optimal fishing period may be 4 hours, therefore less fish will be captured at the time of trap inspection). Previous researchers have stated that more research is required to determine fish behavior upon approach to the leader. Both

visual observations with diving and underwater cameras have been suggested methodology to increase monitoring effort. However, by employing all of the above methods, fish behavior will be disrupted possibly biasing results or driving fish from the recapture location. Use of the telemetry system described will allow passive trap monitoring thereby eliminating these problems, allow complete observation of the fish movement in the vicinity of the trap, and determine the optimal fishing duration and when to haul the trap. Further, detailed observations of fish behavior in relation to the trap and leader may provide insights into improved design and operation.

This system successfully monitored the movement of triploid steelhead trout in the vicinity of the trap and leader (Fig. 6). For the purposes of demonstration, received power levels for only a few fish were plotted along the leader. It should be noted that our trap, lacking the necessary reverse winkers for successful recapture, was not designed to capture fish but rather to field test the telemetry system. For this reason, fish were not retained for long lengths of time following trap entry but were free to swim within the trap and exit at will.

Future users of this system should be aware of several critical considerations for optimal data collection and analysis. First, the importance of leader calibration to allow sufficient data analysis cannot be overemphasized. Calibration should be performed with every trap set-up to ensure the collected data corresponds to the expected received power levels. Within the present study, calibration was only performed at points along the leader. However, it was realized during data analysis that to optimize fish movement monitoring in relation to the leader, calibration should also be performed approximately 1 m from each station on both sides of the leader, again at mid-depth. This would allow more reliable interpretation of power level data to include the fish approach to the leader. Depending on the exact distance of these additional calibration points from the leader hydrophone, received power levels will be similar to calibration data collected at another leader calibration station (Fig. 3). Owing to the nature of this relationship, a received power level associated with a single calibration point on the leader may actually be placed anywhere within the corresponding shaded area of Figure 3. However, by plotting subsequent power levels, the most probable fish track with regards to the leader and trap may be assumed. To increase the power of the study, calibration should be performed at as many points along and away from the leader, with the longest periods of time, considered feasible by the researcher. We calibrated at 3 points along the leader for a minimum of 5 minutes at each of these points which should be considered a minimum.

Second, owing to the intrinsic environmental (depth, temperature and conductivity) and transmitter orientation effects on received signal strength a certain degree of variation should be expected during data interpretation. However, increased calibration effort will produce a p.d.f. with the most consistent values for that environment. During this study, both water conductivity and temperature were changing and possibly affecting received signal strengths resulting in a high degree of power level variation from monitored transmitters. Finally, this particular system only provides horizontal data along the leader. To acquire a more complete data set of fish movement, it is suggested to use a transmitter capable of

measuring and transmitting depth data. This system should be considered a crude, and relatively inexpensive, use of telemetry to monitor movement along a leader. For more accurate positioning, a system capable of precise and accurate three-dimensional positioning may be employed (Cote et al. 1998)

The next step for a successful recapture strategy would be to develop the most optimal recapture trap. Proper research will determine the optimal leader length, depth, twine color and fishing duration to recapture domestic salmonids in the wild. The telemetry system described in this paper also has potential for development of other fishing technologies to optimize traps and ensure they are properly designed to only capture the target species and fish size.

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